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## No. 887.

## RECENT PRACTICE IN RAILS.

An Informal Discussion at the Annual Convention, London, England, July 3d, 1900.

SUBJECTS FOR DISCUSSION.

"The Progressive Increase in Weight; the Increase in Hardness, particularly in Carbon; the Sections in most General Use; the effect of changes in Weight, Composition and Section."

By Messrs. ROBERT W. HUNT, ALBERT LADD COLBY, WILLIAM R. WEBSTER, JOHN F. WALLACE, SIR LOWTHIAN BELL and J. D. SMELT.

ROBERT W. HUNT, M. Am. Soc. C. E.—As America came to Great Britain for the rails used on her first railroads, it is perhaps fitting that this discussion should be presented to the Society in London, and at its first English meeting. Mr. Hunt.

The facts relating to the introduction of rails into the United States, and, later, their manufacture in that country, are historically recorded, and will only be briefly referred to herein. In obtaining the data, free use has been made of James M. Swank's valuable work, "Iron in All Ages."

The first charter for a railroad in the United States was granted by the Legislature of New Jersey in 1815, but the road was never built. In April, 1823, the New York Legislature granted a charter to the Delaware and Hudson Canal Company to construct a canal and railroad for

Mr. Hunt. the transportation of coal from the anthracite coal fields of Pennsylvania to the Hudson River. The road was 16 miles long, but was not completed until 1829. It was on this road that the first locomotive was run in America.

On Saturday, August 8th, 1829, the "Stourbridge Lion," built in England, and weighing 6 tons, made its first trip; but its active life was short, as it was found to be too heavy for the superstructure of the road.

The first American-built engine was operated on the Baltimore and Ohio Railroad, in August, 1830. It was named "Tom Thumb," and was designed and constructed by Peter Cooper, who was somewhat restricted as to materials, as he had to use gun barrels for tubes. The whole machine weighed but 1 ton, and burned anthracite coal. The experiment was successful, and, based on it, later machines were designed and built; the first one of practical size and use being the "Best Friend of Charleston," which was constructed at the West Point Foundry, in New York City, for the Charleston and Hamburg Railroad of South Carolina. It went into active and successful use on that road in December, 1830.

Only some five years intervened between the opening of the first railroad in the world intended for general freight and passenger service—the Stockton and Darlington—September, 1825; and that of the first one in the United States for the same purposes—the Baltimore and Ohio. Its construction was begun on July 4th, 1828, and "cars were put upon it for the accommodation of the officers and to gratify the curious by a ride," in 1829; but it was not formally opened for travel until May 24th, 1830. It was then 13 miles long, extending from Baltimore to Ellicott's Mills, Md.

Thus, in railroad building, as in many other things, the Americans were early disposed to follow closely after their English relatives; and perhaps, like other younger people, were soon not satisfied to follow, but aspired to lead. Thus, the next passenger railroad to be constructed was the Charleston and Hamburg, already mentioned. This was opened for public use in December, 1830. In September, 1833, it was completed for a distance of 135 miles, and was "the longest continuous line of railroad in the world."

The nucleus, from which later came the great New York Central and Hudson River Railroad System, was the Mohawk and Hudson Railroad, chartered by the New York Legislature in 1826, but not begun until 1830, and opened for travel in 1831. It extended from Albany to Schenectady, 17 miles.

There were some earlier railroads, or more properly tramways, built in the United States, but those named were the first really commercial roads.

The rails used on these roads were of wood with flat bar-iron nailed

to their upper surface. The track of the Baltimore and Ohio Railroad is described as consisting of— Mr. Hunt.

"Cedar cross-pieces, and of string-pieces of yellow pine from 12 to 24 ft. long and 6 ins. square, and slightly beveled at the top of the upper side for the flange of the wheels, which at that time was on the outside. On these string-pieces iron rails were placed, and securely nailed down with wrought-iron nails 4 ins. long. After several miles of this description of road had been made, long granite slabs were substituted for the cedar cross-pieces and the yellow pine stringers."

"The iron used for rails was $\frac{1}{2}$ to $\frac{5}{8}$ in. thick by $2\frac{1}{2}$ to $4\frac{1}{2}$ ins. wide. The heads of the nails or spikes holding it down were countersunk in it."

One would judge, from the varying thicknesses and widths, that the specification and inspection were not very rigid.

Notwithstanding these strap-rails being "securely nailed down," it was found that traffic would loosen them, with the final result of their turning up as the wheels passed over them, and forming what were called "snake heads." These would occasionally tear through the bottoms of the cars, and cause more or less inconvenience if not danger to the passengers. So the American engineers again turned to England, where the same difficulties had led to the invention of rails of different sections. It is believed that the first one was the fish-bellied rail, invented by John Birkinshaw, of the Beddington Iron Works, and patented in October, 1820. This rail was held in cast-iron chairs by side keys or wedges. The Baltimore and Ohio Company soon afterward imported some of these rails.

The Stockton and Darlington, and its follower, the Liverpool and Manchester, which was opened in September, 1830, were principally laid with rails of the Birkinshaw type. The Stockton and Darlington also had a few cast-iron fish-bellied rails.

The Clarence rail was another English invention and was considered an improvement on the Birkinshaw. Rails of that pattern were imported into America for the Allegheny Portage Railroad, built by the State of Pennsylvania over the Allegheny Mountains to connect the canals on either side of them. This road was opened in 1833.

In 1834 the Columbia and Philadelphia Railroad was opened. Part of this road was laid with flat rails, but on the greater part the Clarence rails were used. On both roads the rails rested on stone blocks. These roads were in after years absorbed by the Pennsylvania Railroad.

Another English section was the H-rail, which rested in a chair. These were imported, and used on some of the roads. Still later, came the U-rail, known in Wales as the Evans patent, and believed to have been first rolled at the Dowlais Works.

Some of the flat strap-rails were made in America, but all the sectioned ones were imported. Some attempts were made to use American cast-iron rails, but with unsatisfactory results. It was not until

Mr. Hunt. 1844 that the manufacture of sectioned wrought-iron rails was begun in America. A rolling mill was built in 1843 by the Mount Savage Rolling Mill Co., at Mount Savage, Allegheny County, Md., expressly to make rails. Operations commenced in 1844, and for their first rail, which was of the U-section, they were awarded a silver medal by the Franklin Institute of Philadelphia. The rail weighed 42 lbs. per yard. About 500 tons were laid in 1844 on the road then being built between Mount Savage and Cumberland, Md. A short time later they rolled some 52-lb. rails for a road between Fall River and Boston, and in 1845 and 1846 they rolled T-rails. This mill, after being long abandoned, was finally dismantled in 1875.

The T-rail was generally known in Europe as the "Vignoles" rail, after Charles V. Vignoles, an English railroad engineer, who introduced its use there. But it was really invented by Robert L. Stevens, of Hoboken, N. J., President and Engineer of the Camden and Amboy Railroad.

In 1845, the Montour rolling mill, at Danville, Pa., was built expressly to roll T-rails, and in October of that year there was rolled in that mill the first rail of that section made in America.

In 1846, T-rails were rolled by the Boston Iron Works, Boston, Mass.; by Cooper and Hewitt's mill at Trenton, N. J.; by the New England Iron Company, Providence, R. I.; by the Phœnix Rolling Mill Company, Phœnixville, Pa.; by the Great Western Iron Company, Bradys Bend, Pa.; and by the Lackawanna Iron Works, Scranton, Pa.

In the following years the manufacture was taken up by other companies; but owing to the commercial conditions caused by the severity of foreign competition, early in 1850, only two out of the fifteen rail mills in the United States remained in operation.

These early rails were all short; none over 15 ft. long. As the difficulties of manufacture were overcome and the science of track laying progressed, the length was gradually increased until 21 ft. was reached, and was considered the limit. It was not until about 1859 that railway engineers would accept those of greater length.

The first 30-ft. rails rolled in America were made by the Cambria Iron Company, Johnstown, Pa., in 1855; but they could not find sale for them and they were finally used by that company in their mill yards. The first 30-ft. rails to fill an order were rolled by the Montour Company, in January, 1859, for the Sunbury and Erie Railroad Company.

The rolling of iron rails was attended with many difficulties. If the pile of bars was not heated to a sufficiently high degree, the welds would not be perfect; and if heated too highly, the iron would crack in the process of rolling and yield an imperfect product. If the metal was too soft, although the rail might be free from flaws and bad welds,

it would wear out rapidly under traffic. Under all circumstances it was important that the rolling process should be completed as quickly as possible so that the reductions should be made while the iron had lost little of its heat. This, together with some local conditions, led to the invention by John Fritz, Hon. M. Am. Soc. C. E., of the three-high rail train. Three-high sets of rolls had been used for many years in making merchant bars, but it required the application of the "Fritz Yielding Hanging Guides and Driven Feed Rollers," to make them practical for rail rolling. This improvement was put into successful operation at the Cambria Mills in 1857. It has ever since remained as the typical American rail mill. Since the introduction of steel rails there have been several two-high reversing mills on the English plan, used in America; in fact, two of this kind are now running. But the three-high is the American mill, and has permitted the tremendous production which has been attained in later years. Mr. Hunt.

The early mills required the work of handling the material as it passed through the rolls to be done by manual labor, through the use of tongs and hooks. Probably the rolling of iron piles with their necessarily peculiar handling, would have indefinitely continued this, but with the use of solid steel blooms, the troubles lessened and made possible the introduction of automatic machinery. The tong and hook system necessitated the employment of 15 to 17 men, and the production of steel rails was limited to not over 250 tons per turn. Automatic machinery revolutionized this, both as to number of men employed and the possibilities of production.

It was the writer's fortune to introduce the first driven rail-mill tables, those in the works of the Albany and Rensselaer Iron and Steel Company, Troy, N. Y., in March, 1884. These were in front of the finishing rolls, and worked so well that an automatic arrangement was soon after placed in front of the roughing rolls. This latter arrangement was more particularly designed by Mr. Max M. Suppes, then the master mechanic of the works, and now the general manager of the Lorain Steel Company, Lorain, Ohio. Naturally, these devices were protected by letters patent. From this start other inventions were made, and many improvements by other American engineers have followed, until the present American rail mill, capable of turning out 50 000 tons of finished rails per month, has been developed.

It was the writer's fortune to become connected with rail making in 1856, and among his earliest recollections is the statement that the users of rails had in service certain makes which had been and were giving results impossible to be obtained from any of more recent manufacture. How familiar that statement must sound to many of you, and as of recent date!

Then, as now, the question demanded an answer, and many sought for the solution.

Mr. Hunt. The first iron rails were made from straight puddled bars. These bars were about 1 in. thick and were placed one upon another, until a pile of sufficient weight and height was formed; the pile was then reheated and rolled into rails. And it was to the formation of that pile that inventive genius was applied.

From an investigation of the fracture of some of the rails which had given satisfaction, it was discovered that the pile of bars from which they had been rolled, had been entered in the rolls edgewise, thus bringing the line of welds between the bars in a vertical instead of horizontal position. This presented a different structure to the wheel wear, and seemed to be logical. Based on that supposition many rails were so rolled, and the writer believes that the scheme was patented.

Where the rail was rolled with the layers of the pile in a horizontal position, particular attention was given to the character of the top bar, which would, of course, form the wearing surface of the rail. Cold-short or granular iron was used for it, while the remainder, or at least the flange of the rail, was of fibrous iron.

At one time a rail with a puddled-steel head—or rather with the top bar of the pile of puddled steel—found much favor, but, owing to the difficulty of obtaining uniformly good welds, the results were not satisfactory. Some of these so-called steel-headed rails had the top bar of what was known as silicon steel.

Another plan, on which much money was spent, was to hammer a puddled ball, or weld two puddled balls together, under a steam hammer, and draw them into a slab 2 to 2½ ins. thick, which was used on the top of the rail pile. Under an order from the Pennsylvania Railroad Company, the Cambria Iron Company, in whose employ the writer was then serving, erected a special steam hammer, and made several thousand tons of such rails. Their service was somewhat disappointing, and the practice was abandoned.

At that time, as since, commercial conditions controlled. The railroads had the worn-out rails on their hands, and, regardless of whether or not the practice would give satisfactory results, they adopted a system of having the old rails re-rolled into new ones. At first a certain percentage of new iron was specified, but as the necessities for immediate economies increased, that demand was eliminated from the contracts, and the new rails were composed entirely of the old ones. The best practice was to make a pile of old rails, break it down into bars, which were piled upon each other, and then rolled into rails. But presently this was found to be too expensive to successfully meet the cry for cheaper rails, and only the top and bottom of the piles were formed from re-worked iron, the center being composed of from three to six pieces of old rails.

From the many re-workings, the cheapening of the process of manufacture, and the increasing demands of traffic, the wear of the

iron rails become more and more unsatisfactory, until it seemed as though, from that cause alone, the limit of railway development had been reached. Such situations frequently occur in earthly affairs; and seldom if ever has the occasion failed to be met by a solution of its difficulties. In this case, came the invention of Bessemer. Mr. Hunt.

It is a historical fact that the first rail ever made from Bessemer steel was placed on the Midland Railroad, of England, early in 1857, at a point where iron rails had sometimes to be renewed within three months; and it remained there until June, 1873, some sixteen years, during which time about 1 250 000 trains and any number of detached engines and tenders passed over it.

We all realize that without such an innovation as Bessemer's, the subsequent tremendous expansion of railway development would have been physically impossible.

Railway managers were timid about using steel rails, and in America many attemps were made to produce a satisfactory rail having an iron base and web, with a steel-capped top. None was satisfactory, and the Bessemer steel rail soon conquered the situation.

The first steel rails laid down by an American railroad were imported by J. Edgar Thomson, President of the Pennsylvania System.

The first to be manufactured in America were rolled at the mills of the North Chicago Rolling Mill Company, Chicago, Ill., on May 24th, 1865, from ingots produced in experimental steel works at Wyandotte, Mich. They were not many in number, and were made on the regular iron rail rolls of the mill. Several of the rails were put in local railway tracks and gave good service.

The first production of steel rails in the United States, on a commercial order, was at the Cambria Iron Company's mill, in August, 1867, from ingots made by the Pennsylvania Steel Company, near Harrisburg, Pa. The converting works of that company were completed some time in advance of its rail mill, which led to an arrangement under which the ingots were sent to Johnstown to be hammered into blooms which were then reheated and rolled into rails. The steel was made under the management of the late Alexander L. Holley, M. Am. Soc. C. E., then in charge of the Pennsylvania Steel Company. George Fritz was the Chief Engineer and General Superintendent of the Cambria Iron Company, and Alexander Hamilton, Superintendent of the rail and other mills, while the writer was in direct charge of the steel department.

It is a matter of some interest, that the ingots were drawn down by the steam hammer which had been installed some years before to make the hammered iron slabs for the Pennsylvania Railroad Company's rails. From this time, the production in America of Bessemer steel rails increased rapidly.

Mr. Hunt. For a time after the starting of the Pennsylvania Steel Company's Bessemer Works, the ingots were cast from the top, on the then-accepted English plan. Mr. Holley's mind was not so constituted that he could long follow any beaten track without an effort to do better work on some other line. Thus, he introduced the bottom-casting of ingots; pouring the steel into a central octagonal mould about 14 ins. diameter at the bottom and 10 ins. at the top, from the bottom of which the metal flowed through connecting gates into four surrounding moulds 8½ ins. square. This plan was adopted after consultations with Mr. George Fritz, who had rolls turned to take the 8½-in. ingots. The central or sprue ingots were hammered into blooms. It was found that the small ingots rolled satisfactorily, while, on the contrary, the central ones cracked badly during working.

This led to much discussion and consultation among the operative officers of the Cambria Company and Mr. Holley, the result of which was that John E. Fry, then superintendent of the Cambria Iron Company's iron foundry, suggested the use of a rammed-up center sprue, 4 ins. in diameter, connecting through fire-brick gates with surrounding ingots; the sprue and gates to be treated as scrap. This plan answered admirably.

While in charge of the experimental Bessemer Works at Wyandotte, Mich., in the interest of the Cambria Iron Company, the writer had developed a manner of bottom-casting ingots. Mr. Holley, having protected his plan by a patent, Mr. Fry and the writer united in patenting theirs, and their interests and those of Holley were consolidated. For some years after this, practically all bottom-casting of ingots in America was licensed under these patents. After a time the price of rails became so much reduced that the loss incident to the scrap of the center sprue and bottom gates made in bottom-casting became a serious matter, and while it was and is impossible to cast as sound, and hence as good, ingots from the top, the better plan was abandoned.

At first, all the American Bessemer's works pursued the English plan of reducing the ingots to blooms under steam hammers. This was so at the Pennsylvania and Troy Works. The success in rolling the 8½-in. ingots at Johnstown led to the invention of the American blooming mill, and this soon completely superseded the steam hammer in rail making.

This idea originated with Mr. George Fritz. Holley and he were intimate friends and exchanged views freely. Holley had severed his connection with the Pennsylvania Steel Company, and returned to the Troy, N. Y., Works. There he built a three-high blooming mill. While it had tables, their rollers were not power-driven, and the ingots had to be pushed into the rolls and turned over on the tables by hand. Soon after, George Fritz built a blooming mill at Johns-

town, in connection with a Bessemer converting plant, and put into use his patented ideas of driven rollers, hydraulically controlled movable rolls, and a "turning over and sliding from pass to pass" device, christened by the mill hands a "go-devil," which permitted the economical handling of larger ingots. This was the birth of the American blooming mill. In perfecting his plans George Fritz had the benefit of the advice of his brother John, then manager of the Bethlehem, Pa., Works. Mr. Hunt.

Perhaps these details apply more to rolling-mill practice than to the rails themselves; but the writer thinks that they have played a most important part in relation to the character of steel rails, and are pertinent to the subject. Holley started the innovation by which the production of steel ingots has been increased so greatly. Fritz gave the blooming mill, which would not only take care of all that was sent to it from the converting works, but like Oliver Twist, ask for more; and the late Capt. William R. Jones, Robert Forsyth, M. Am. Soc. C. E., and several others, built rail mills which were not satisfied with the amount of steel sent to them by any blooming mill. This has all been magnificent. It has made possible undreamed-of low prices for steel rails. It has helped to build railroads, but has it improved the quality of the rails produced?

Steel rails, when first manufactured, replaced iron rails, which, through their deteriorated quality and the increased duty demanded of them, were giving most unsatisfactory service. Some of the early steel rails failed, but most of them were so much better than the best of their predecessors that such failures did not excite adverse comment. They were of what would now be considered light sections, and thus in their production from the 6 × 6-in. or 7 × 7-in. blooms from which they had been rolled, had received much work, and at a comparatively low temperature. In the writer's judgment the greatest factors in the production of good rails are covered by the words "work and temperature." All steel men know that work at high heats does not change the grain of steel at all in proportion to work given at lower temperatures.

For years after the introduction of steel rails a 65-lb. per yard section was considered a heavy one. In fact, in America it was the heaviest used, and much the largest percentage was not over 60 lbs. These were rolled from 7 × 7-in. blooms. The ingots from which the blooms were made were generally 12 × 12 ins. After the bloom was formed it was examined carefully after becoming cold, and all cracks and mechanical imperfections were chipped out. Then, after slow heating, with care to avoid too high a temperature, the blooms were rolled into rails by light reductions. While this was being done, if a defect showed itself, the process was stopped until it was chipped out. Now, this slow work at a moderate and steadily decreasing tempera-

Mr. Hunt. ture, resulted in a fine grained metal, which, of necessity, no matter what may have been its chemical composition, would give greater resistance to the wear of traffic than could be possible from the coarser grained steel which is in the head of the heavier and more rapidly rolled sections of to-day.

By waiting long enough the things of the past always become the best. That is, provided the past is not examined too closely. It must be remembered that the early rails replaced a much inferior article; in fact, created a revolution in railway maintenance of way. Hence, if a few from any cause failed, it excited little comment; they were quietly replaced by others. After a while these failures were forgotten, and the whole lot of existing rails was instanced as an example of what rails should be. Another thing which must not be overlooked is, that the early steel rails had the ultimate stress of traffic applied by slow degrees. In other words, the traffic to which they were subjected when first put in service was for them light duty. Heavier rolling stock, faster and more frequent trains, came gradually. The old-time rails, which are in these later days so reverently mentioned, had been subjected to a cold-rolling process before being given their severest task. To-day an 80-lb. rail is hardly cold before a 175 000-lb. locomotive, hauling 100 000-lb. capacity cars at 35 miles per hour; and limited expresses of heavy Pullmans at 60 miles per hour are thundering over it.

The details of manufacture of steel rails changed, not only in America, but also in England and other countries. This had to be, and it would to-day be as impossible to return to the earlier methods as to restore the service of stage coaches.

In 1876, the writer presented a paper at the Philadelphia meeting of the American Institute of Mining Engineers, on "The History of the Bessemer Process in America," and with great pride chronicled the fact that the North Chicago Bessemer Works, under the management of Robert Forsyth, had, in a single month, produced 6 457 gross tons of ingots, and that it led the world's records. These ingots were all rolled into rails. To-day, the North Chicago Converting Works and rail mill are abandoned, their places having been taken by the present South Chicago plant of the Illinois Steel Company, in which rail mill the largest month's production has been 58 103 gross tons of standard-sectioned rails.

The Edgar Thomson Works of the Carnegie Steel Company has made 47 074 gross tons of rails in a calendar month. Other American mills are turning out a large tonnage, but it is believed that the foregoing at present hold the record.

While the faster work of modern practice has somewhat altered the character of the steel in rails, it must not be assumed that the product has been increased without any regard to other considerations.

That is not true; on the contrary, the outward character or finish of the rails has been improved to a radical extent. While working fast, the improved machinery is also reliable, and the care exercised in keeping true to section, square sawing, accurate drilling and straightening of both line and surface, yield results which it would have been impossible to obtain in the earlier days. In fact, the requirements of the railways, in consequence of increased weight and speed of traffic, etc., have made it imperative that such finished rails should be given them. Mr. Hunt.

It is not desired to draw any invidious comparisons, but, in the writer's judgment, American makers are to-day not only turning out the most rails, but at the same time the best finished ones now produced. Moreover, foreign rails, imported into the United States and Canada during late years, have not worn any better than American rails.

It has been stated that examining into the past sometimes disproves assumptions. So that, while in the earlier days rail steel and rails were made with all the time and care which has been described, all the rails produced were not satisfactory. In fact, the experience of the Pennsylvania Railroad was such that their chemist, Charles B. Dudley, M. Am. Soc. C. E., made an elaborate investigation into the chemical composition of their satisfactory and unsatisfactory rails. His deductions were presented to the American Institute of Mining Engineers in October, 1878, and elicited a memorable discussion. Dr. Dudley concluded that rail steel could be too hard for good service, even though the rails did not actually break. His conclusions were in favor of chemically softer metal. Some of those discussing the matter thought and stated that the size of the rail sections should not be ignored.

As the accredited authority of the great Pennsylvania Railroad, Dr. Dudley's views carried added weight, and it resulted in a demand in America for softer rails. The writer thinks that no one to-day will attempt a defence of that position. In fact, the practice did not long prevail. But it cannot be safely claimed that the present rails, whether made in America or imported from Europe, are giving absolutely satisfactory results. They are permitting the accomplishment of work which, but a little while ago, would have been considered an impossibility. Still, if engineers had ever been absolutely satisfied with that which was, progress would have halted. Heavy-sectioned rails which will yield better results than those now being obtained are needed. Our railway organizations have generally become so situated financially, that they need no longer be limited to the immediate present in the policies of their administrations.

In the old countries, railroads were built because there was a population whose needs demanded them. In this country, they were often built because there was a tremendous amount of country and no popu-

Mr. Hunt. lation. This led to cheap construction, but while we still have plenty of room for more people, our country has become rich enough to justify the best of railroads, and, in fact, imperatively demands them. The successful operation of the roads themselves can be only on such a basis. As the railroads increased in number, and their requirements varied in accordance with their traffic and profiles, and being constructed and operated by many different men, it was natural that not only the weight of rails used, but their sections, should differ. In fact, almost every road had its own particular section. The variations between many were slight, but sufficient to necessitate the use of special rolls in their manufacture. This had become so pronounced, and caused so great an investment of capital on the part of rail makers and loss of time in changing from one section to another, etc., that Mr. Holley, in his characteristic progressive spirit, attacked the situation in a paper presented to the American Institute of Mining Engineers, in February, 1881. In this he stated that, answering his inquiries, the eleven Bessemer mills then making rails in the United States had sent him drawings of 188 patterns which were considered standard ones, and that 119 patterns of 27 different weights per yard were regularly manufactured. Mr. Holley gave drawings of many of these and pointed out the absurdity of some of the variations. His paper attracted wide interest, but it was a difficult matter to reach. However, its discussion was continued by others later. Mr. P. H. Dudley, who had devoted much time to the study of the wear of rails, and who invented a recording car for the examination of the rails, contributed papers on the subject to both the scientific press and societies. J. D. Hawks, M. Am. Soc. C. E., then Chief Engineer of the Michigan Central Railroad, advocated certain sections, as also did D. J. Whittemore, Past-President, Am. Soc. C. E., and the writer also presented a series of sections, in a paper read before the American Institute of Mining Engineers, February, 1899.

This Society appointed the committee on "The Proper Relation to Each Other of the Sections of Railway Wheels and Rails," which performed its duties in a thorough manner; and following and resulting from its reports, the Society appointed a committee to consider and recommend a series of Standard Rail Sections. This was in 1891, but the final report of the Committee was not made until June, 1893.* During the intervening years the members of the committee had worked faithfully; consulted personally and by correspondence with many of the chief engineers of the railroad systems of the country, and agreed upon all points but one. One member, Mr. George S. Morison, differed with the Chairman, Mr. G. Bouscaren, and with Messrs. Foster Crowell, Virgil G. Bogue, S. M. Felton, J. D. Hawks, E. T. D. Myers, Samuel Rea, Thomas Rodd, A. M. Wellington, F. M.

* *Transactions*, Am. Soc. C. E., Vol. xxviii.

Wilder, and Robert W. Hunt, as to the width of heads of the proposed sections, and, on that point, made a minority report. Mr. Hunt.

As secretary of the committee during the latter part of its work, the writer knows the difficulties and labors of the task, and naturally, is gratified to know that the recommended rail sections are to-day practically the standard ones for American railroads. During 1899, quite 75% of all the rails rolled by American rail mills were of what are commercially known as the American Society sections.

Geographical and commercial conditions must govern. When the Bessemer process was first introduced in America, imported English pig irons were used in making the steel. American irons were experimented with and gradually displaced foreign irons. This practice first prevailed in the works located west of the Allegheny Mountains. They soon relied entirely upon charcoal pig, made from Lake Superior and Missouri ores. This was much higher in phosphorus than the English irons, but the results obtained from it were so satisfactory that the investigation continued and extended to the use of American mineral fuel irons, both anthracite and coke. After a time these completely displaced both foreign coke and American charcoal brands, in both western and eastern works.

It happened that, while the most available western ores contained percentages of phosphorus fully up to the limit possible for Bessemer uses, the cheapest eastern ores were quite low in that obnoxious element. Hence, it has been and is a fact, that some of the rail makers located east of the Alleghenies can produce rails low in phosphorus contents, while using the lowest priced pig metal. The opposite is true of the western mills. These geographical and commercial conditions have led to the use of entirely distinct chemical specifications in the two districts—at least by some of the leading makers in those districts.

The heavier equipments and higher speeds required more rigid road beds, which could only be obtained by heavier sectioned rails. These were gradually adopted. It was naturally expected that as the sections were increased so would the resulting amount of service yielded by the rails. From the very first, the results obtained were disappointing, and the writer doubts whether we will ever succeed in getting results as satisfactory as those yielded by the lighter sections. As the area of the section is increased, so, of necessity, will the work upon the steel in forming it be decreased; and as the resulting mass is enlarged, so will the amount of heat retained in it at the time of the final reduction through the rolls be increased. In the writer's judgment, it will be found that the most satisfactory results will be obtained by so modifying the rolling system that the final pass (or better, passes) shall be given after the temperature of the partially formed rail has been lowered. This is not by any means a new idea, but as yet it has not been carried out in a manner calculated to obtain the best results.

Mr. Hunt. Some years ago, Mr. F. A. Delano, now Superintendent of Motive Power of the Chicago, Burlington and Quincy Railroad, in the interest of that company, had some rails rolled at the South Works of the present Illinois Steel Company, then owned by the North Chicago Rolling Mill Company, on such lines and under his personal supervision. Unfortunately, these rails were of a peculiar section, which was not continued, but the writer believes that the wear of the metal itself was encouraging.

The satisfactory wear being given by rails renewed by the "McKenna Process" at the Joliet and Kansas City Mills of the McKenna Steel Working Company, bears very strongly on this point. Mr. McKenna takes rails which have become unfit for further service in main line tracks, from having become rough in surface, through flow of metal, or other causes; or which have become curve-worn on the side of the head; and, after carefully removing any fins which have been formed on the upper edges of the heads by metal flow, charges them into a long furnace, and, when heated to not more than 1 500° Fahr., they are drawn from the furnace by a mechanical contrivance which at the same time removes any scale which may have formed on their surface, and slightly upsets or flattens the section. The rail is then passed through a set of forming rolls, from which it is carried forward to another set, in which it is given a finishing pass. The rail is then sawed hot, and cold-straightened and drilled in the usual manner. And while the section has been somewhat reduced, the original finishing sections and heights have been maintained.

Now, the steel has been given finishing work at low temperature, and examination has proven that the grain of the metal in the head of the rails has been "fined." But, more important than all, the wear of the renewed rails is promising to be much more satisfactory than that obtained from new rails of heavier sections. This treatment of rails is no longer in an experimental state, as it is over five years old, and there are nearly 100 000 tons of renewed rails in service on the Chicago, Milwaukee and St. Paul; Atchison, Topeka and Santa Fé; Wabash and other large systems. One chief engineer, on whose road there are many of these rails, says: "No rail ought to be used at all until after it has been renewed."

The writer has already stated that, owing to geographical, and hence commercial, conditions the chemical specifications under which rails are made differ east and west of the Allegheny Mountains. In the Scranton and Bethlehem District what are known as the New York Central and Hudson River Railroad specifications, which were originally formulated for that road by Mr. P. H. Dudley, are regarded as the standard; while for the mills west of the Alleghenies, a different formula is followed. Some of the main railway systems insist on buying under their own chemical specifications, no matter where made.

The writer has gone on record so often, as believing that in the absence of work at low heats, incident to the present method of making heavy-sectioned rails, it is important to increase the carbon with the section to as great an extent as the phosphorus present will permit, without incurring risk from breakage, that it seems unnecessary to repeat the arguments. Mr. Hunt.

At the Atlanta meeting of the American Institute of Mining Engineers, in October, 1895, the writer presented a set of specifications for "Steel rails of Heavy Sections Manufactured West of the Alleghenies." In accordance with these specifications thousands of tons have been made and used with satisfactory results. During the last two years the western makers have declined to limit the phosphorus to less than 0.10 %, but, in fact, have been making steel with a fraction less than that amount—say 0.09 to 0.096 per cent. And he regrets to say that in many cases they insist that the amount of carbon shall be less than that which he has advocated. He believes, however, that gradually, higher carbon will prevail, and certainly has not had any cause to change his mind on the subject. His experience as a steel-rail maker, and as an observer of the wear of steel rails of many sections and diverse chemical composition, leads him to advocate: *First*, work, after careful heating of the steel, and continued until its temperature has been much reduced. *Second*, that the carbon percentages shall be increased in proportion to the increase of rail section, the ultimate amount being, of necessity, limited by the contained percentage of phosphorus. In all cases he advocates the use of drop tests, on samples from each heat of steel.

At present many of the American railway engineers use the drop test, but none of them demands the static or tensile tests insisted upon by so many engineers of other countries; nor does the writer think there is any necessity for these latter. The chemical analyses and drop tests are all sufficient.

As a matter of record, the writer gives the chemical formulas contained in his specifications of 1895, in accordance with which, as stated, thousands of tons of rails have been made and have given good results. And while at present the western makers decline to limit their steel to 0.085% phosphorus, the writer certainly sees no reason to decrease the carbon. In other words, so many rails have been made and proven safe with quite as much carbon as given in these specifications, and with 0.10% phosphorus, that the writer does not think the former element should be made less, certainly not until the details of manufacture have been changed.

The standard specifications of the Louisville and Nashville Railroad Company are also given, as they cover both Bessemer and basic open-hearth steel rails.

The so-called New York Central and Hudson River Railroad Com-

Mr. Hunt. pany's specifications are also appended; and the present standard specifications of the western rail mills.

### Robert W. Hunt's Specifications.

Sec. 8.—The carbon in the 70-lb. section shall not be below 0.43% nor over 0.51 per cent. In the 75-lb. section, not less than 0.45% nor over 0.53 per cent. In the 80-lb. section, not less than 0.48%, nor over 0.56 per cent. In the 90-lb. section, not less than 0.55%, nor over 0.63 per cent. In the 100-lb. section, not less than 0.62%, nor over 0.70 per cent.

The phosphorus shall not exceed 0.085 per cent.

The silicon shall not be below 0.10 per cent.

The remainder of the chemical composition of the steel to be left to the maker's judgment.

### Louisville & Nashville Railroad Specifications.

The steel used for rails shall contain carbon as follows: For 58¼-lb. steel rail from 0.42 to 0.52 of 1%; for 70-lb. steel rail 0.47 to 0.57 of 1%, and for 80-lb. steel rail 0.55 to 0.65 of 1%, and not more than 0.085 of 1% of phosphorus, or 0.07 of 1% of sulphur. Silicon, 0.15 to 0.20 of 1 per cent.

When the steel used for the rails has been made by the basic open-hearth process, it should be of the following chemical composition: For 58¼-lb. steel rail, from 0.45 to 0.52% of carbon; for 70-lb. rail, 0.50 to 0.57%; for 75-lb. rail, 0.55 to 0.60%; for 80-lb. rail, 0.62 to 0.67 per cent. The steel used for all rails shall contain silicon from 0.10 to 0.20%, 0.15% being preferred; manganese, 0.90 to 1%; phosphorus, not to exceed 0.05%; sulphur, not to exceed 0.05 per cent.

### New York Central & Hudson River Railroad Specifications.

| | 65-lb. | 70-lb. | 75-lb. | 80-lb. | 100-lb. |
|---|---|---|---|---|---|
| Carbon | 0.45 to 0.55 | 0.47 to 0.57 | 0.50 to 0.60 | 0.55 to 0.60 | 0.65 to 0.70 |
| Silicon | 0.15 to 0.20 | 0.15 to 0.20 | 0.15 to 0.20 | 0.15 to 0.20 | 0.15 to 0.20 |
| Manganese | 1.05 to 1.25 | 1.05 to 1.25 | 1.10 to 1.30 | 1.10 to 1.30 | 1.20 to 1.40 |
| Sulphur | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 |
| Phosphorus | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| Rails having carbon below will be rejected | 0.43 | 0.45 | 0.48 | 0.53 | 0.60 |
| Rails having carbon above will be rejected | 0.57 | 0.59 | 0.62 | 0.65 | 0.70 |

### Specifications of the Western Rail Mills.

| Section 1. | 50-lb. up to 60-lb. | 60-lb. up to 70-lb. | 70-lb. up to 80-lb. | 80-lb. up to 90-lb. | 90-lb. up to 100-lb. |
|---|---|---|---|---|---|
| Carbon | 0.35 to 0.45 | 0.38 to 0.48 | 0.40 to 0.50 | 0.43 to 0.53 | 0.45 to 0.55 |
| Phosphorus | not over 0.10 | not over 0.10 | not over 0.10 | not over 0.10 | not over 0.10 |
| Silicon | not over 0.20 | not over 0.20 | not over 0.20 | not over 0.20 | not over 0.20 |
| Manganese | 0.70 to 1.00 | 0.70 to 1.00 | 0.75 to 1.05 | 0.80 to 1.10 | 0.80 to 1.10 |

ALBERT LADD COLBY, M. Am. Soc. Mech. Eng. (by letter).—Mr. Hunt very appropriately opens the discussion by remarking that: Mr. Colby.

"As America came to Great Britain for the rails used on her first railroads, it is perhaps fitting that this discussion should be presented to the Society in London, and at its first English meeting."

To this the writer would like to add that as America now exports rails to British Colonies, it is also fitting, perhaps, that at this first English meeting, a few words be addressed to English engineers in friendly criticism of foreign rail specifications, and a few practical suggestions given as to modifications which can safely be made in their specifications without any danger of obtaining an inferior product from American rail mills, and with the decided practical advantages of lower prices and more prompt delivery.

No discourtesy is intended to our hosts, the Institution of Civil Engineers, in this evident effort to advertize American steel. The halls of our technical societies, and the columns of our technical press are just as freely open to our English friends, and no one is quicker to appreciate and adopt foreign ideas, patents or products than the American engineer, and the American purchasing agent.

The following official statistics show the rapid increase in the tonnage and value of steel rails exported from America in recent years:

| | Gross tons. | Value. |
|---|---|---|
| 1894 | 12 229 | $323 880 |
| 1895 | 8 807 | 222 661 |
| 1896 | 72 503 | 1 712 716 |
| 1897 | 142 808 | 2 949 901 |
| 1898 | 291 038 | 5 787 384 |
| 1899 | 171 272 | 6 122 382 |

In the following brief review, the requirements of foreign rail specifications will be compared with those contained in a proposed standard American specification for rails, recently framed by Committee No. 1 of the American Section of the International Association for Testing Materials, and which specification will be presented by this Committee at the Annual Meeting of the American Section, in October, 1900, for discussion and adoption as the standard American specification.

### 1. THE PROCESSES OF MANUFACTURE SPECIFIED.

In a review of forty-one foreign rail specifications, eight were found which limit the manufacturer to the use of "The best English or Spanish hematite pig iron and charcoal spiegeleisen." This requirement, of course, cannot be complied with in American mills, nor in the present state of the art, does it seem a necessary stipulation in any case, particularly as, if strictly interpreted, it seriously limits competition.

Mr. Colby.

2. The Chemical Properties Specified.

(a) *Carbon.*—In 63% of the forty-one foreign specifications reviewed, limits in carbon are specified, and in the majority of these cases a range of carbon of from 0.10 to 0.15% is given. This is in general accord with American practice, except that the proposed American standard specification increases the carbon gradually with the increased weight of section, specifying in each case a range of 0.10 per cent. This is in accord with Mr. Hunt's suggestion that "The carbon percentages shall be increased in proportion to the increase of rail section."

The actual percentages of carbon given in foreign specifications will not be discussed in detail. The proper structure to insure safety and wearing qualities is what is desired in rails; and as the percentages of carbon, and other hardening elements which will give this structure, vary with the finishing temperatures, the chemistry must be changed to suit the varying conditions of manufacture. Some American rail mills have recently been successful in experiments looking toward the finishing of rails at a lower temperature than at present in vogue in America, without diminishing the present output. This recently patented improvement is in accord with Mr. Hunt's suggestion that:

"In the writer's judgment, it will be found that the most satisfactory results will be obtained by so modifying the rolling system that the final pass (or better, passes) shall be given after the temperature of the partially formed rail has been lowered."

In short, an international standard composition for rails is utterly impracticable, and it is useless for any country, or any engineer, to assert that their composition is the best, and, therefore, should be adopted in all countries.*

(b) *Phosphorus and Sulphur.*—Thirty-two per cent. of the foreign specifications reviewed, called for a phosphorus and sulphur of 0.06% or below. Rails meeting these requirements will be furnished in America, at, of course, a considerably higher price than charged for rails of 0.10% phosphorus, which latter forms by far the largest proportion of the product of American rail mills. Many thousands of tons of American rails of 0.10% phosphorus have given satisfactory service under severe conditions. The increased cost of 0.06 or 0.08% phosphorus rails, over that of rails containing 0.10% phosphorus does not, in the opinion of many competent judges in America, obtain a correspondingly safer or better rail from American mills.

Mr. Hunt states that:

"Owing to geographical, and hence commercial, conditions the chemical specifications under which rails are made differ east and west of the Allegheny Mountains. In the Scranton and Bethlehem District what are known as the New York Central and Hudson River Railroad specifications, which were originally formulated for that road by Mr.

* See C. P. Sandberg's paper: "The danger of using too hard steel rails." *Journal Iron and Steel Institute*, No. 2, 1898, pp. 76-110; especially p. 106.

P. H. Dudley, are regarded as the standard; while for the mills west of the Alleghenies, a different formula is followed." Mr. Colby.

The Bethlehem District referred to is no longer a producer of rails, and the writer happens to be in a position to know that the New York Central and Hudson River Railroad Company has very recently abandoned the 0.06% phosphorus limit recommended by Mr. P. H. Dudley, and has purchased rails of 0.10% phosphorus. It can hence be safely asserted, that, as far as tonnage is concerned, practically all American roads now use rails of 0.10% phosphorus.

(c) *Silicon and Manganese.* –About one-half of the foreign rail specifications examined mentioned limits in silicon and manganese. The silicon specified varies from 0.06% to 0.25 per cent. The manganese varies between the wide limits of 0.40% and 1.20 per cent. American mills would not be inclined to furnish rails on a specification limiting the manganese to 0.40%, the requirement mentioned in one specification examined. The American standard specification for rails states that silicon shall not exceed 0.20%; and gives a range of 0.30% in manganese, the limits varying with the increased section between 0.70 and 1.10 per cent.

In general, it may be stated that the strict adherence, by a foreign engineer, to a specified complete chemical composition, independent of the varying conditions of manufacture, and the rejection of large lots of rails solely because the sample, assumed to represent the lot, exceeds in some respects the specified chemistry, compels his client to pay much more than is necessary to obtain a first-class rail to-day from American mills.

### 3. Samples for Analysis.

Some foreign specifications require that every heat of rail steel shall be analyzed for phosphorus and arsenic, and stipulate that if the phosphorus and arsenic exceed 0.06% the heat is not to be used. It has been proved conclusively that arsenic should not be classed with phosphorus in its effect upon the physical qualities of steel.* Furthermore, as there is no rapid method by which both phosphorus and all of the arsenic can be determined, the ingots of each blow could not be held for analysis, but must be rolled into rails and subsequently rejected if the analysis shows a phosphorus and arsenic of over 0.6 per cent. This burden, with the unnecessarily frequent analysis demanded, will not be assumed by the American manufacturer without substantial remuneration, and will more often result in a refusal to bid unless this requirement of the specification be withdrawn.

Another very arbitrary clause in certain foreign specifications, states that each 500 tons of finished rails will be accepted or rejected on the

*F. W. Harbord and A. E. Tucker, *Journal, Iron and Steel Institute*, No. 1, 1888, pp. 183-196, and No. 1, 1895, pp. 131-132 and 127-128.
J. E. Stead, *Journal, Iron and Steel Institute*, No. 1, 1895, pp. 77-140.

Mr. Colby. analysis of a piece of one rail, selected by the engineer; said analysis to be made, at the contractor's expense, by an independent chemist, selected by the engineer. In American mills the rails pass over several cooling beds, and are drilled on many sets of presses. Without great additional labor, therefore, it is impossible to land the finished rails of consecutive heat numbers in 500-ton piles in the yard, to await the complete analysis of the independent and probably distant chemist. In the light of all that has been published, and candidly admitted by the manufacturer, as to the unavoidable variation in composition even of the different parts of a section of rail, to say nothing of the variation of different rails of a blow, how can an engineer conscientiously accept or reject 500 tons of rails from the analysis of a single rail?

### 4. The Physical Properties Specified.

(*d*) *Tensile Strength and Elongation.*—With a specified chemical composition, a drop test, and, in most cases, a dead-weight test also, tensile strength and elongation is an unnecessary requirement. In fact, when carbon, and other hardening elements are specified, and strictly adhered to, the tensile strength and elongation should not also be made the subject of specification. Tensile specimens represent, at best, only a small part of the cross-section of the rail. If taken from the center of the head, the results are affected by the segregation of the hardening elements, and do not represent the portion of the metal subjected to greatest strains in service; if taken from the exterior surface, the results are apt to be affected by the presence of a few partly welded blow holes. In neither case, therefore, can the tensile specimen be considered as fully representing the rail from which it was cut, much less any lot of rails from which the sample was selected.

(*e*) *Drop Tests Specified.*—All the foreign specifications reviewed, very properly contain a drop test; some of the drop tests specified, however, are open to considerable criticism. Where chemical composition is specified, and faithfully followed, the drop tests should not include a certain maximum deflection, but should simply specify that the piece of rail shall not break under a single blow on the head, the tup falling from a height increasing with the weight of the rail section. Where the engineer prefers to include a certain maximum deflection in the drop test, besides specifying that the piece of tested rail shall not fracture, the percentage of carbon should be omitted from the chemical requirements. Either method will insure a safe hard rail; but a specified range of 0.10% in carbon is perhaps a better and more prompt means of securing and maintaining uniformity in the product.

(*f*) *Dead-Weight Tests Specified.*—This transverse test under static load should include a determination of the yield point, and, by means of still heavier loads beyond the yield point, the determination of

greatest permanent deflection. The test may be looked upon as unnecessary when the chemical composition is fully specified and when the ability of the finished rails to withstand shock is determined by a drop test. However, the requirements of the dead-weight tests contained in foreign specifications are met without difficulty by American mills. Seventy per cent. of the forty-one specifications examined specify a dead-weight test, but in quite a number only a weight is used which will give no permanent set. The test is, therefore, frequently regarded in American mills as at least unnecessary, for, when the loads specified are within the elastic limit of the steel, the deflections are merely factors of the section of the rail. Mr. Colby.

5. Finish.

Some foreign specifications require, even after the templets have been approved by the engineer, resident abroad, that a section of the rail 12 ins. long must be submitted to the foreign engineer and approved in writing before the general rolling can proceed. This is a needless delay, as confidence can be safely placed in the skill and integrity of American manufacturers.

In a number of foreign specifications the permissible variations in height of sections are too rigidly drawn to allow for the unavoidable wear of the rolls. Smoothness of track is in nowise jeopardized by an allowance of $\frac{1}{64}$ in. under and $\frac{1}{32}$ in. over the specified height; they are the variations permitted by the best American railroads. A number of foreign specifications allow a less variation in length of rail than $\frac{1}{4}$ in., which is the uniform practice of American railroads.

Most foreign specifications allow a variation in weight of 1% for individual rails. This can be easily reduced to 0.50% for the entire order, but the rails should be paid for on actual, and not estimated, weights.

6. Inspection.

American mills are noted for their willingness to afford the inspector every facility to enable him to satisfy himself that the rails are being furnished in accordance with the specifications. In return, they have a right to expect from a foreign purchaser inspection which will not delay manufacturing operations. This is by no means always realized, and, as it is a frequent cause of expensive and annoying delays, it is a proper subject of comment.

The inspectors sent to American mills are frequently unfamiliar with rail inspection, and are, therefore, too strict in their inspection, and too slow in their decisions. Again, when the specifications require all four sides of every rail to be examined for flaws, all holes gauged, each rail tested for length and squared on each end, and stamped in four places by the inspector's mark, and also require him to be present

Mr. Colby. at the testing, to weigh 1% of the rails, and to watch the loading of the rails to see that only those bearing his stamp are loaded, it is manifestly unfair to the manufacturer to send but one inspector to the mill and expect the manufacturer to conform his product to the number of rails that one inspector can pass upon, in nine or ten hours of the twenty-four. Lack of inspectors frequently necessitates a change of rolls at the mills, and has delayed the departure of vessels on which the rails were being loaded. Assuredly, a sufficient number of inspectors to inspect the entire product of the mill each day should be furnished.

Some foreign specifications require that all rejected rails shall be piled up and kept until the completion of the contract, so that, at any time, the inspector may check them with the numbers entered in the book; and that no rejected rail shall be sold or broken until the completion of the contract. This is manifestly unfair to the manufacturer, because on a large contract, not continuously rolled, a considerable tonnage of second-quality rails might be tied up, which might otherwise be sold. Some foreign specifications state that the final acceptance of the rails and splice bars shall be at the port of delivery. This is unreasonable; final acceptance should be based on tests and inspection made at the place of manufacture.

The writer is confident that foreign purchasers have no desire to knowingly include in their specifications, requirements which, while securing no more efficient product, operate to limit competition and increase the cost of inspection and the price of product. This thought prompted the foregoing criticism of foreign rail specifications, which, it is hoped, will result to the mutual advantage of the foreign customer, and the American mills.

Mr. Webster. WILLIAM R. WEBSTER, M. Am. Soc. C. E.—From Mr. Hunt's discussion one might be led to believe that it was the usual practice to use high carbon steel in our rails. But such is not the case, as is shown by the fifteen American rail specifications given in the table prepared by Committee No. 1, of the American Section of the International Association. This table gives 0.45% to 0.55% carbon for the 100-lb. rails used by many of our railroads.

Most of the rails are rolled to the sections of this Society, the rails of 70 lbs. per yard and under giving better satisfaction than the heavier rails. It seems to the speaker that this difference in results is due more to the higher finishing temperature in rolling the heavier sections of rails than to any other cause. The large mass of metal in the head of the heavier rails carries the heat much longer than the thin metal in the flange, and the work of rolling has to be stopped on account of cold flange, when the metal in the head is still too hot. By putting more metal in the flange, to carry the heat, the head of the rail can be finished at a much lower temperature, and a closer grain

obtained. This is a matter which the Society could take up and investigate to advantage. Mr. Webster.

As a check on the finishing temperature in rolling, the speaker suggests that a limiting clause be put in the specifications as to the percentage of shrinkage which will be allowed in a rail, from its finishing temperature in rolling to the normal temperature. This amount of shrinkage in a 30-ft. rail is a good measure of the finishing temperature, and it only remains to prove by experiment just how much shrinkage it is safe to allow. Or, in other words, what finishing temperature should be used to produce the best results.

It has been claimed by some who take an extreme view of the present practice, that we are now "hardening our rails by the carbon and squirting them through the rolls." But, as a matter of fact, we know better to-day than ever before the true bearing of the chemical elements on the physical properties of the steel, and the change of structure due to the mechanical work of rolling or forging at the proper finishing temperature.

The beneficial effects of finishing a heavy rail at the proper temperature are shown in re-rolling heavy rails which have not given good service in use. This is accounted for by the annealing action of the furnace in heating the rails up to a low heat for rolling, thus breaking up the coarse grain, and not heating high enough to form it again, the final work of rolling on the head is at a low temperature, the flange being in a condition to allow this work at the proper temperature.

The report of the English Committee appointed by the Board of Trade "To Enquire into the Loss of Strength in Steel Rails through Use on Railways," will appear shortly, and give us much valuable information. It will, no doubt, be the true starting point for international rail specifications.

Many of our specifications, at the present time, have ear-marks in them showing the suggestion of the manufacturers in one section as against those of another, or suggestions of the makers of basic Bessemer steel as against those making acid Bessemer steel. What is wanted is to get rid of all this and take the whole matter up on its merits from an engineering and metallurgical standpoint. From the present indications it looks as though the International Association for Testing Materials would be invited by the Iron and Steel Institute to hold the next Congress in England in the fall of 1901. It is to be hoped that this will be brought about, as there is no society better fitted to assist in this great work than the Iron and Steel Institute of England.

The following is quoted from Appendix VII of the report of the English Committee:

"It is probable that the Board of Trade will expect or desire the Committee to recommend an analysis for the guidance of engineers or

Mr. Webster. manufacturers, which shall, in the judgment and experience of the Committee, be the composition of the steel to ensure a safe and good wearing rail. I therefore suggest, after careful consideration from the points of view of a manufacturer and user, that, exclusive of the iron, a steel rail should have the following range of composition:

| | Minimum. | | Maximum. |
|---|---|---|---|
| "Carbon | 0.35 | to | 0.50 |
| "Silicon | 0.05 | to | 0.10 |
| "Sulphur | 0.04 | to | 0.08 |
| "Phosphorus | .... | to | 0.08 |
| "Manganese | 0.75 | to | 1.00 |

"Mr. Edward P. Martin, of Dowlais, considered these suggested figures with me and approves them.

"(Signed) E. Windsor Richards."

On referring to the report of the American Committee No. 1, we find that the chemical limits in rails from 50 to 75 lbs. were as follows:

| | | |
|---|---|---|
| Carbon | 0.35 to | 0.50 |
| Silicon | not over | 0.20 |
| Sulphur | ............ | |
| Phosphorus | not over | 0.10 |
| Manganese | 0.70 to | 1.05 |

These recommendations are remarkably close, especially when one considers that the work was done in different countries by these Committees entirely independent of each other, and that in America only acid Bessemer steel is used for rails; while in England both the acid and basic Bessemer steel are used.

The results compared above indicate that the suggestions which have been made, that each country prepare standard or representative specifications for each class of material, can be easily carried out. It is not too much to expect that, at the General Congress of the International Association for Testing Materials, to be held in 1901, each country will present representative specifications, and that international specifications will be agreed upon.

The English Committee have been working at a great disadvantage, as in all cases of broken rails examined they knew nothing whatever of the heat treatment of these rails in rolling, and as this has such a great influence on the final structure of the rail, had it been known it would have accounted for many of the abnormal results referred to in the report. It is to be hoped that the work of the Committee of the Board of Trade will be continued, that rails will be rolled under known conditions, and that rails from the same heat of steel will be finished hot, medium and cold, in order to get at the true value of the mechanical work of rolling at different temperatures. This will give valuable information in one of the most important lines of research, which has been too much neglected up to the present time.

Mr. Wallace.

JOHN F. WALLACE, President, Am. Soc. C. E.—Two of the American engineers who have spoken on this question represent inspecting consulting engineers, and one the manufacturers. The speaker would like to say one word from the purchasers' side. The railroads themselves, up to date, have had very little to say about the specifications of the rails used in America, and mainly on account of business reasons. The railways to the east of the Allegheny Mountains have naturally been confined to the use of rails manufactured in that district, first, on account of the fact that the manufacturers were also the customers of the railroads, and produced a great deal of freight and traffic; and secondly, because they were nearer the point of consumption. The same controlling elements exist in the mills in the vicinity of Chicago. The roads of the West, tributary to Chicago, were naturally inclined to purchase rails from the Chicago mills, and the result has been that the roads east of the Allegheny Mountains have been compelled to use rails manufactured in their district, which could be manufactured from the ores east of that point; and the roads in the Mississippi Valley and the West have generally been confined to the use of the rails manufactured in Chicago. A great many roads have endeavored to enforce their own specifications. On the other hand, the mills have endeavored to require the railroads to accept their specifications, coupled with a guarantee that any rails affected during the period of 5 years should be replaced.

The railroads, to-day, through their engineers and their own special organization, which is looking after this particular matter, are now taking up the question of adopting specifications and asking the manufacturers to conform to them. The matter is now in the hands of a Committee of Engineers, who do not propcse to draw up specifications which are impossible to fill; but intend to find out, from the character of the ores in different parts of the country, and from the processes of manufacture, what are the possibilities, and will endeavor to decide on specifications which are practical and common-sense. In the formation of such specifications, however, they expect to consult with the manufacturers and with the inspecting engineers.

In reference to phosphorus, some years ago on the Illinois Central Railroad, on a section of road where the traffic was exceedingly heavy, there was in use a 60-lb. rail, laid in 1878. Twenty years after that rail was laid, it was removed in order to replace it with an 85-lb. rail. The rail gave such extraordinarily good service that it was analyzed and found to run as high as 0.012 and 0.015 phosphorus—from 50 to 100% more than the specifications were then calling for.

Sir Lowthian Bell

SIR LOWTHIAN BELL, M. Inst. C. E.—There are probably few questions connected with the manufacture and behavior of rails while in use which demand a more extended area of examination than those raised by Mr. Hunt. The opinions about to be given are those gathered from many years' experience as a manufacturer supple-

Sir Lowthian Bell.

TABLE No. 1.—RESULTS OF TESTS MADE AT PARK LANE STORES, GATES-MIDDLE AND BOTTOM OF INGOTS, AS PER SIR LOWTHIAN BELL'S, 3 FT. APART.

| Distinguishing No. of rail...... | 991 | | 992 | | 993 | | 994 | | 995 | | 996 | | 997 | | 998 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ingot No......... | 1 | | 1 | | 1 | | 2 | | 2 | | 2 | | 3 | | 3 | |
| Part of ingot taken from..... | Top. | | Middle. | | Bottom. | | Top. | | Middle. | | Bottom. | | Top. | | Middle. | |
| | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. |
| Results of tests.. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. |
| | 5 | $\frac{5}{8}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{5}{8}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{5}{8}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{11}{16}$ |
| | 5 | $1\frac{1}{8}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{1}{4}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{1}{8}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{3}{16}$ |
| | 7 | $1\frac{3}{4}$ | 7 | $1\frac{3}{4}$ | 7 | $1\frac{13}{16}$ | 7 | broke | 7 | $1\frac{3}{4}$ | 7 | $1\frac{3}{4}$ | 7 | $1\frac{13}{16}$ | 7 | $1\frac{13}{16}$ |
| | 10 | $2\frac{3}{4}$ | 10 | $2\frac{11}{16}$ | 10 | $2\frac{3}{4}$ | .. | ...... | 10 | $2\frac{11}{16}$ | 10 | $2\frac{5}{8}$ | 10 | $2\frac{3}{4}$ | 10 | $2\frac{3}{4}$ |
| | 15 | $4\frac{3}{16}$ | 15 | 4 | 15 | $4\frac{3}{16}$ | .. | ...... | 15 | $4\frac{1}{8}$ | 15 | $4\frac{1}{16}$ | 15 | $4\frac{1}{8}$ | 15 | $4\frac{3}{16}$ |
| | 21 | broke | 21 | $6\frac{1}{8}$ | 21 | $6\frac{7}{16}$ | .. | ...... | 21 | broke | 21 | $6\frac{1}{4}$ | 21 | broke | 21 | broke |
| | .. | ...... | 27 | broke | 27 | broke | .. | ...... | .. | ...... | 27 | $9\frac{15}{16}$ | .. | ...... | .. | ...... |
| | .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... | 27 | broke | .. | ...... | .. | ...... |
| Sum of falling feet (breaking blow halved)... | $52\frac{1}{2}$ | | $76\frac{1}{2}$ | | $76\frac{1}{2}$ | | $13\frac{1}{2}$ | | $52\frac{1}{2}$ | | $103\frac{1}{2}$ | | $52\frac{1}{2}$ | | $52\frac{1}{2}$ | |

Note.—These samples taken from

| Composition— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Phosphorus.... | 0.043 | 0.048 | 0.043 | 0.040 | 0.044 | 0.053 | 0.043 | 0.050 |
| Sulphur........ | 0.050 | 0.060 | 0.070 | 0.050 | 0.060 | 0.060 | 0.070 | 0.060 |
| Carbon........ | 0.560 | 0.560 | 0.570 | 0.500 | 0.510 | 0.550 | 0.560 | 0.560 |
| Silicon......... | 0.069 | 0.066 | 0.057 | 0.072 | 0.072 | 0.084 | 0.081 | 0.069 |
| Manganese .... | 0.950 | 0.960 | 0.970 | 1.020 | 1.030 | 1.030 | 0.950 | 1.060 |
| Arsenic......... | 0.061 | 0.065 | 0.061 | 0.028 | 0.018 | 0.044 | 0.049 | 0.032 |
| Iron by difference.......... | 98.267 | 98.241 | 98.229 | 98.290 | 98.266 | 98.179 | 98.247 | 98.169 |

The weight of the rail was 90 lbs. per yard, the length tested

mented by a still longer experience as a director of one of the most important railroads in the United Kingdom. A life so spent seems to embrace all the conditions essential to the present discussion.

It may be well here to describe the mode of testing used in ascertaining the resistance to fracture offered by the rails under examination:

A weight of one ton (2 240 lbs.), and capable of being detached at any point of its travel, was raised by steam power between two girders of considerable height. The usual plan was to raise the weight a very few feet at first, and to increase the height of fall gradually, until fracture was effected. No account was taken of the acceleration of the fall, and therefore of the power, by the continued operation of gravita-

HEAD, ON 18 PIECES OF NEW "HEMATITE" STEEL RAILS, FROM TOP, INSTRUCTIONS. TESTED JUNE 20TH, 1898; BALL, 1 TON; BEARINGS,

Sir Lowthian Bell.

| 999 | | 1000 | | 1001 | | 1002 | | 1003 | | 1004 | | 1005 | | 1006 | | 1007 | | 1008 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | | 4 | | 4 | | 4 | | 5 | | 5 | | 5 | | 6 | | 6 | | 6 | |
| Bottom. | | Top. | | Middle. | | Bottom. | | Top. | | Middle. | | Bottom. | | Top. | | Middle. | | Bottom. | |
| Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. | Fall | Def. |
| ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. | ft | ins. |
| 5 | $\frac{11}{16}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{5}{8}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{5}{8}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{11}{16}$ | 5 | $\frac{5}{8}$ | 5 | $\frac{5}{8}$ |
| 5 | $1\frac{1}{8}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{1}{8}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{1}{8}$ | 5 | $1\frac{1}{8}$ | 5 | $1\frac{3}{16}$ | 5 | $1\frac{1}{8}$ | 5 | $1\frac{1}{16}$ |
| 7 | $1\frac{3}{4}$ | 7 | $1\frac{7}{8}$ | 7 | $1\frac{13}{16}$ | 7 | $1\frac{13}{16}$ | 7 | $1\frac{13}{16}$ | 7 | $1\frac{13}{16}$ | 7 | $1\frac{3}{4}$ | 7 | $1\frac{7}{8}$ | 7 | $1\frac{3}{4}$ | 7 | $1\frac{11}{16}$ |
| 10 | $2\frac{5}{8}$ | 10 | broke | 10 | $2\frac{3}{4}$ | 10 | $2\frac{3}{4}$ | 10 | $2\frac{3}{4}$ | 10 | $2\frac{11}{16}$ | 10 | $2\frac{5}{8}$ | 10 | $2\frac{13}{16}$ | 10 | $2\frac{11}{16}$ | 10 | $2\frac{9}{16}$ |
| 15 | $4\frac{1}{16}$ | .. | ...... | 15 | $4\frac{3}{16}$ | 15 | $4\frac{3}{16}$ | 15 | $4\frac{3}{16}$ | 15 | $4\frac{1}{8}$ | 15 | $4\frac{1}{8}$ | 15 | $4\frac{1}{4}$ | 15 | $4\frac{1}{8}$ | 15 | $3\frac{15}{16}$ |
| 21 | broke | .. | ...... | 21 | $6\frac{7}{16}$ | 21 | $6\frac{1}{2}$ | 21 | $6\frac{3}{8}$ | 21 | $6\frac{1}{2}$ | 21 | $6\frac{5}{16}$ | 21 | $6\frac{1}{2}$ | 21 | broke | 21 | 6 |
| .. | ...... | .. | ...... | 27 | broke | 27 | broke | 27 | broke | 27 | broke | 27 | broke | 27 | broke | .. | ...... | 27 | broke |
| .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... | .. | ...... |
| $52\frac{1}{2}$ | | 22 | | $76\frac{1}{2}$ | | $76\frac{1}{2}$ | | $76\frac{1}{2}$ | | $76\frac{1}{2}$ | | $76\frac{1}{2}$ | | $76\frac{1}{2}$ | | $52\frac{1}{2}$ | | $76\frac{1}{2}$ | |

six ingots, three out of each.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.051 | 0.059 | 0.073 | 0.070 | 0.060 | 0.060 | 0.059 | 0.057 | 0.070 | 0.062 |
| 0.060 | 0.060 | 0.060 | 0.060 | 0.050 | 0.060 | 0.050 | 0.040 | 0.050 | 0.050 |
| 0.560 | 0.550 | 0.570 | 0.560 | 0.560 | 0.580 | 0.570 | 0.500 | 0.550 | 0.580 |
| 0.069 | 0.066 | 0.072 | 0.063 | 0.069 | 0.066 | 0.063 | 0.072 | 0.087 | 0.084 |
| 1.050 | 1.060 | 1.070 | 1.040 | 1.040 | 1.070 | 1.030 | 0.870 | 0.930 | 1.060 |
| 0.045 | 0.051 | 0.026 | 0.039 | 0.061 | 0.059 | 0.045 | 0.049 | 0.057 | 0.063 |
| 98.165 | 98.154 | 98.129 | 98.168 | 98.160 | 98.105 | 98.183 | 98.412 | 98.256 | 98.101 |

was 10 ft., and in each case the running head was up.

tion, because this did not exhaust by any means the disturbing causes of the calculation. The chief of these is the unknown absorption of power by the deflection of the rail at each blow. The plan followed was to sum up the various falls and count the last at one-half its real amount. The estimate, therefore, is one of comparison only.

In evidence of irregularity in results the case of the trials of bull-headed steel rails of 90 lbs. per yard may be given. One of these gave way under a united fall of 23 ft., while a second one required for its fracture 199 ft. Chemical analyses of several specimens were made without throwing any light on this very great difference in the fall required for rupture. This will be best reserved for cases to be presently described.

Sir Lowthian Bell. Those members who have read the classic work of Professor Henry Marion Howe, who confirmed observations made at the Clarence Works, will remember his description of the absorbing power of liquid steel in occluding gaseous matter, which latter was given off as the molten metal cooled. He naturally inferred that the uppermost portion of the ingot would contain the largest portion of the liberated gas which was imprisoned in spherical cells. When the ingot was rolled into a rail these cells were flattened but not entirely obliterated.

Trials were made by dividing each ingot into three parts, which were marked top, middle and bottom, and a rail was rolled from each. Six rails from each section were rolled and were exposed to the following test. A reference to Table No. 1 shows that the fractures took place as follows:

From the "Tops" at an average of 48.9 ft., "Middles" 64.5 ft., and the "Bottoms" 77 ft., and, further, that the analyses fail to connect these with any differences in chemical composition.

A committee appointed by the British Board of Trade has concluded a long inquiry, in which evidence of an exhaustive character was given. In it the data just quoted, besides much more of a highly important character, are to be found.

The changes in molecular structure, supplemented by microphotographic plates, are described at great length and with great ability by Professor Roberts Austen.

Mr. Smelt. J. D. SMELT, M. Inst. C. E.—The speaker has had occasion recently to advise the Argentine Great Western Railway Company on the relative value of American and British tenders for rails.

The section tendered upon, 72.8 lbs. per yard, was designed by the speaker in 1893, and has been rolled several times since that date in Great Britain and also in the United States. It is shown in full black lines in Fig. 1. The enquiry was issued for rails to be manufactured to the speaker's specification. One of the leading American firms tendered in accordance with the Argentine Great Western section, but in accordance with their standard specification for quality. The differences between the two specifications are shown in the table on Fig. 1, the chief differences being the high phosphorus and silicon of the American specification and the lower tensile strength and elongation, coupled with the somewhat inconsistently easy falling-weight test.

The price per ton quoted by the American firm was considerably lower than the British quotations, and the principal questions to decide were: First, what is the relative durability of 43-ton steel as compared with 38-ton steel; and, secondly, the amount of attendant risk due to the presence of high phosphorus and silicon, which, in a rail with a somewhat thin flange, might be considerable.

With regard to durability, it appeared to be approximately in pro-

Mr. Smelt.

| | Argentine Gt. Western | American |
|---|---|---|
| **Chemical Composition** | | |
| Carbon | 0.4 to 0.5 | 0.4 to 0.5 |
| Silicon | up to 0.08 | up to 0.2 |
| Sulphur | up to 0.06 | up to 0.05 |
| Phosphorus | up to 0.06 | up to 0.10 |
| Manganese | up to 1.0 | 0.7 to 0.9 |
| **Falling Weight Test on 3-Ft. Bearings** | | |
| Weight of Tup | 2240 lbs. | 2000 lbs. |
| Height of Fall | 13 ft. | 17 ft. |
| Number of Blows (without fracture) | 4 | 1 |
| Deflection under 1st Blow | 2 to 3 ins. | |
| " " 2d. " | 4 to 5 ins. | |
| **Tensile Test** | | |
| Tensile Strength (Tons per square inch) | 43 | 38 |
| Elongation | 12% in 10 ins. | 12% in 2 ins. |
| Contraction of Area | 20% | |

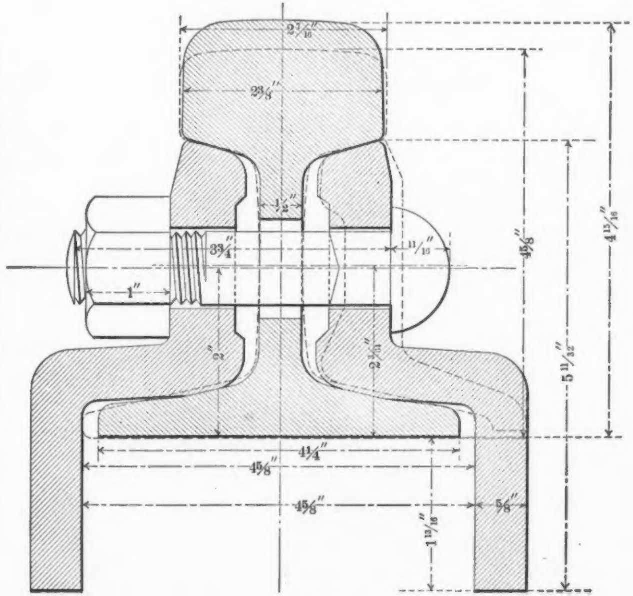


Fig. 1.

Mr. Smelt. portion to the tensile strength, which is, in the speaker's opinion, independent of the means adopted to produce it; that is to say, it matters little whether the high or low tensile strength is due to the difference in temperature of the material during rolling, or to difference in chemical composition. Perhaps Mr. Hunt and other members can give some practical information on the subject.

Another point, to which attention should be directed, is the difference in the American standard sections of 70-lb. rails and fish-plates (shown in dotted lines on Fig. 1), as compared with the sections designed for the Argentine Great Western Railway.

In the Argentine Great Western rail, the speaker allowed for a wear of $\frac{5}{8}$ in., and finds that the depth of the head of the American standard is about $\frac{5}{16}$ in. less, which would appear to indicate about half the life, apart from the difference in tensile strength.

With regard to fish-plates, the Argentine Great Western deep section shown on Fig. 1 was designed to make the joint of equivalent strength to the solid rail when worn, and the results of tests prove the design to be correct in this respect.

The American fish-plates of angular design cannot, therefore, be of the same relative strength, especially when taking into account the very soft material of which they are made.